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SIMULATION OF ELECTRONIC WARFARE WITH THE COMMEL MODEL

AUGUST 1977

PREPARED BY
SYSTEMS FORCE MIX DIRECTORATE

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This paper describes the process of extending the COMMEL II Model to include one-sided EW play. Results from executing the new version of COMMEL are also discussed.

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SUMMARY

There is a lack of applied simulation analysis of electronic warfare (EW) in a division combat environment. The COMMEL II combat simulation model was extended to create such an analytic tool. This paper describes the process of development of COMMEL II.5 (the extended model). The EW features included are jamming and direction finding (DF). The model development approach is described from system operational description to event and input representation on the model. The COMMEL II.5 Model was also executed in assessment runs using scenarios for an 8-hour battle. In these, the Red EW was shown to have statistically significant adverse effects on Blue force combat and communications performance. A resulting observation was that COMMEL II.5 demonstrates the potential for comparative analysis of simulated division combat with and without EW. The effects can be measured in terms of changes in combat status and in performance of electronic systems. Another observation was that the model should be extended to include a broader representation of intercept intelligence.

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SIMULATION OF ELECTRONIC WARFARE WITH THE COMMEL MODEL

CHAPTER 1
INTRODUCTION

1-1. PURPOSE. This paper describes both the extension of the COMMEL Model to incorporate simulation of electronic warfare (EW) and an assessment of the resultant model. The term EW as applied in this paper includes use of electronic countermeasures (ECM) and electronic warfare support measures (ESM). The modified model was designated COMMEL II.5. The ultimate aim was the plausible representation of EW effects on combat outcome through interaction with communications. The COMMEL II Model is a computerized division level simulation of combat which dynamically integrates communications system performance with tactical events. The basic model is described in more detail in Appendix C.

1-2. RELATION TO OTHER STUDIES AND AUTHORITY. The Director of Telecommunications, Command and Control, Office Deputy Chief of Staff for Operations and Plans (ODCSOPS) has sponsored several studies at CAA to supplement the findings of the United States Army Training and Doctrine Command (TRADOC) study of the Integrated Tactical Communications System (INTACS). USACAA was to investigate the relative influence on combat of two alternative communications systems (i.e., current communications and the INTACS system). The results of the initial phase of the investigation were published in an earlier CAA study report.* In the second phase it became necessary to analyze further the effects of ECM (jamming) and to include simulation of active ESM (direction finding). The formulation of the COMMEL II.5 Model was in response to that need. The results of this second phase study, utilizing the COMMEL II.5 Model, are reported in a separate CAA study report.**

1-3. PROBLEM. The Army did not have a fully computerized simulation of EW in a comprehensive division-level communication and combat environment. Current models either simulated combat in

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*US Army Concepts Analysis Agency, (U) "Contribution of Integrated Tactical Communications System (INTACS) Alternatives to Division Combat," CAA-SR-76-5, Apr 76.

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**US Army Concepts Analysis Agency, (C) "Contribution of Integrated Tactical Communications System (INTACS) Alternatives to Division Combat-II," CAA-SR-77-2, Jul 77. (U)

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detail while neglecting communications structure or vice versa. The COMMEL II Model provided the only comprehensive framework for introducing EW in a combat/communications interface. However, the model simulated only a rudimentary jamming feature of ECM with no representation of any aspect of ESM. It was necessary to investigate and modify COMMEL II to broaden the simulation of EW processes with SIGINT.

1-4. OBJECTIVE. The objectives of the COMMEL II extension were to:

a. Determine the feasibility of modifying the COMMEL II Model to expand the EW simulation.

b. Define a logical event structure describing the EW operations to be modeled.

c. Modify the COMMEL II Model to include the events of the new EW logic.

d. Exercise the modified model (COMMEL II.5) and assess the validity of results.

e. Document the new EW features of the COMMEL II.5 Model.

Efforts to meet objectives a. through c. above were initiated during the methodology for the second phase INTACS Study. Objectives d. and e. are unique to this study.

1-5. LIMITATIONS. a. Only Red EW operations were modeled.

b. No Blue EW operations were modeled since the Red force communications were simulated as 'perfect' communications, i.e., there were no degradations or failures in the system. Current computer storage limitations require model operation under this option.

c. Only the Direction Finding (DF) aspect of ESM was modeled.

1-6. METHODOLOGY. The model modification effort was structured into the following sequence of steps:

a. <u>Actual System Operation</u>. The experience of military officers at USACAA provided extensive background in development, application and assessment of EW and in the evaluation of INTACS. Their experience was used to define a reasonable 'real world' representation of EW processes.

b. Model Examination. The COMMEL II Model was examined to locate routines, variables and logic which could be extended and applied to portray as many aspects as possible of the 'real world' EW system. Software constraints such as computer storage limitations also had to be considered.

c. Logical Flow. An event chain was built to represent the DF process. Each event determined new input variables and code which were constructed and merged into COMMEL II to form COMMEL II.5.

d. Input Data Assembly. After COMMEL II had been modified, values of reasonable input data for test and assessment of COMMEL II.5 were gathered.

e. Test/Assessment. Using CAA INTACS Alternatives study scenarios, COMMEL II.5 was exercised with and without Red EW. Plausibility and validity of results were assessed in light of scenario conditions and the design of the EW model logic.

1-7. MODEL ASSESSMENT. a. General. The assessment results discussed herein are not intended to be a study of the effectiveness of alternative communications systems. The INTACS system is the only one discussed in this report. The scenarios and effectiveness/performance measures employed demonstrate the operation and plausibility of the EW features of COMMEL II.5.

b. Definitions. The assessment results were expressed in terms of measures of performance (MOP) and measures of effectiveness (MOE). An MOP measures only technical direct effects of a system. Frequently, this is in terms of localized system performance with minimal regard for interactions or consequences in a larger environment. An MOE is broader in scope and reflects the impact of a system on total force effectiveness. The ideal MOE should reflect the contribution of the EW system in terms of 'value added to the force'. Since the COMMEL II.5 Model provides a dynamic interface of communications and combat performance, the derived measures can relate communications system status with and without EW to the ability of the force to accomplish its mission. In this manner, second order effects of EW can be assessed.

1-8. ORGANIZATION OF PAPER. This paper is organized into the following parts. Chapter 1 is an introduction and overview. Chapter 2 describes the methodology development of the EW simulation. Chapter 3 describes the assessment and evaluation of the extended model. Chapter 4 gives observations derived from the study. Appendix A names the study contributors. Appendix B is a glossary of specialized terms and acronyms. Appendix C describes the COMMEL II Model which was used as a base for development.

Lastly, Appendix D describes the EW input structure in the extended model.

CHAPTER 2

EW SIMULATION DEVELOPMENT

2-1. GENERAL. The base tool for developing the COMMEL II.5 simulation methodology was the COMMEL II Model. The development process described in this chapter required a definition of EW operations and a means of representing these in an extended model. New EW input data also had to be formulated and assembled.

2-2. EW OPERATIONS. For purpose of feasibility in modeling, the EW operational aspects were condensed as follows:

a. ECM. ECM (jamming) is used to neutralize enemy communications links. Jamming is of limited duration on any single channel since the user can shift frequency. Ideally, a single jammer will have sufficient bandwidth and power to render several channels unusable. Use of ECM can impede the flow of information among enemy units.

b. ESM. The uses of intercepted signal intelligence (SIGINT) are broad. Much SIGINT analysis requires the use of collateral intelligence sources. Some aspects of SIGINT could not be adequately modeled in this development within the available time. Restriction to a basic and direct application was necessary. The application represented herein is the location of hostile radios through direction-finding (DF) sensors (i.e., ESM). A triad of sensors might reasonably be deployed near the forward edge of the battle area (FEBA). Each sensor then acquires a line of bearing to enemy radios. The DF intelligence generated from all sensor units is merged with collateral intelligence. Commanders can use the combined intelligence as combat information for artillery targeting or as intelligence for tactical operations. A stylized event flow diagram of such a DF intelligence process is shown in Figure 2-1. The event sequence described is a reasonable application scheme. It was selected for plausibility of use in a model 'test base', not for total comprehensiveness.

2-3. MODEL EXAMINATION. a. Overall Model. The Commel II Model is a fully computerized simulation of division level combat and communications with resolution to company level. The simulation has four submodels: the tactical submodel, the communications submodel, the background traffic submodel and the message processor submodel. A detailed description of model operation can be found in Appendix C.

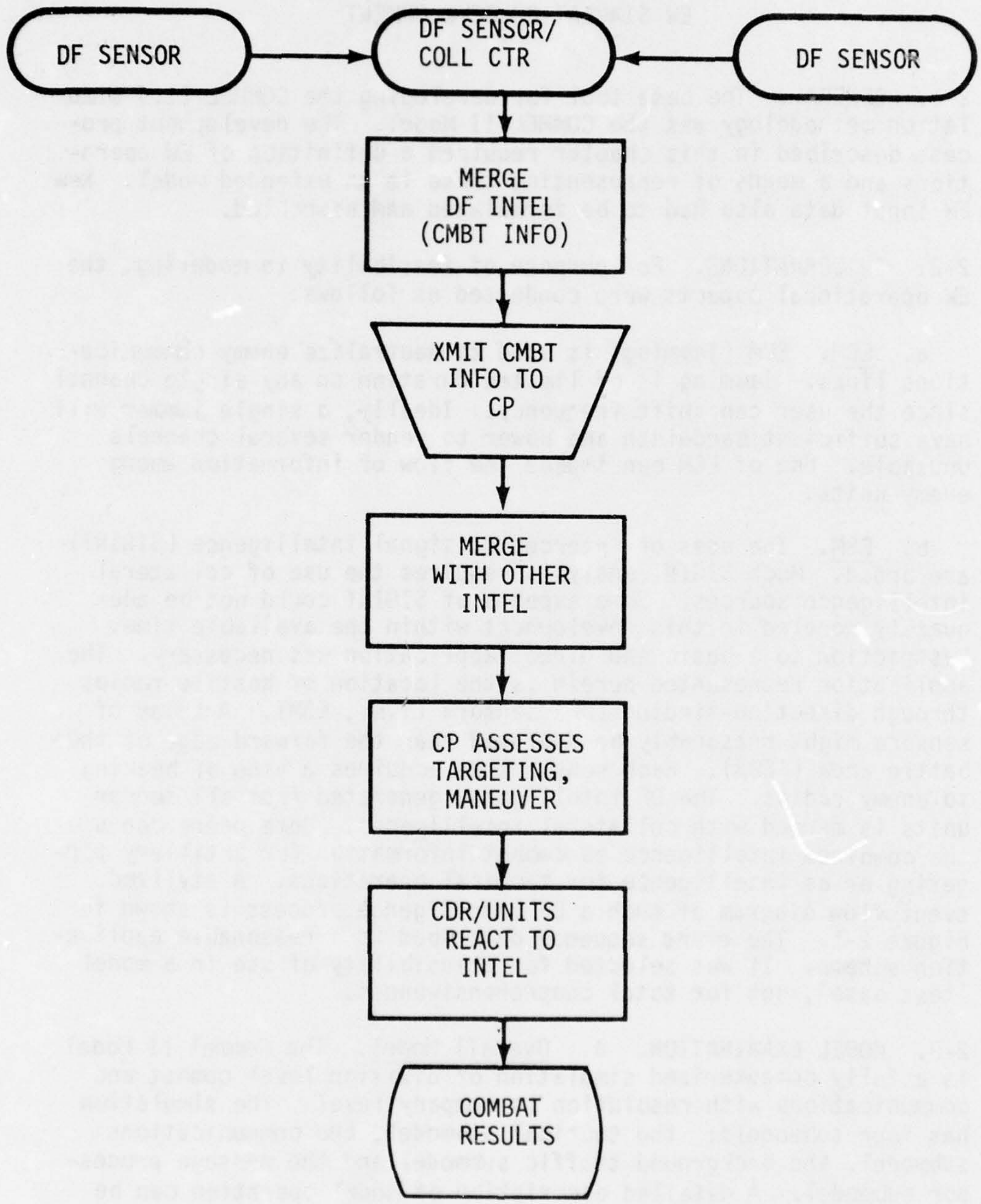

Figure 2-1. Operation and Flow of DF Intelligence

b. ECM. The existing ECM feature in the COMMEL II Model was the jamming of enemy radio nets. Using specified inputs, the model randomly selects the appropriate number and types of links to be jammed. Each selected link is jammed for 15 simulated minutes. At any instant of time, only the specified (input) proportion of links are jammed. This representation of jamming was considered to be an adequate 'first cut' and was left unaltered so that development effort could be concentrated on SIGINT features.

c. ESM. The tactical and message processor submodels of COMMEL II were suitable for adaptation to include ESM. These adaptations were linked with the model routines generating long range intelligence. To use these to simulate DF intelligence, a link with 'on-air' radio status was established in the message processor submodel. Special ESM input variables also had to be defined and linked with several model routines.

(1) Long Range Surveillance. The COMMEL II subroutine FARSEE simulates the acquisition of long range intelligence on enemy units. Such information is typically gathered by air observers, radars, drones and similar devices. The routine uses input factors describing a set of long range intelligence devices and their sensing characteristics. Intelligence is then collected and relayed upward at game time intervals of 15 minutes. The sensor information acquisition rate is determined by the inherent sensor sensitivity, composition (type and strength) of the unit detected, its distance from the sensor and the nature of intervening terrain. Subsequent to acquisition, each sensor unit relays its intelligence to higher echelons where it is merged with information from other sources (e.g. short range forward observers). The level of intelligence is a factor in artillery targeting, generation of status reports and in commit/decommit actions. In addition, the level of intelligence directly affects movement status and attrition rates.

(2) Surveillance Modifications. Much of the intelligence process described above is applicable to DF acquisitions. However, a DF sensor when suitably placed will have only minimal short range terrain interference. The sensing process must interact with the message traffic in the communications environment. The COMMEL II Model was modified to enable definition of special sensor devices representing the DF system. These special devices operate much like a standard COMMEL II long range sensor except that terrain interference is minimized. In addition, a time-dependent link was established between the tactical and message processor submodels. The link makes the DF intelligence rate dependent on the time since the last radio transmission by the detected unit. The types of radio to be scanned (e.g. SSB, FM) are input

parameters. The mechanisms of COMMEL II already provide for the merging and fading of intelligence. These were not modified. The artillery targeting subroutines of COMMEL II had to be extended to include evaluation criteria for target selection using DF intelligence. Decision rules for selection of other tactical actions (e.g. maneuver patterns) based on DF information were judged too complex to model in a first stage attempt.

2-4. LOGICAL EVENT CHAIN. A scenario base was constructed which included a triad of Red divisional electronic warfare (EW) units. Each EW unit possessed one DF sensor. The system features were represented by a DF intelligence event chain. The chain begins with sensor acquisition of DF information and ends with the formation of artillery target lists incorporating the new intelligence. The chain is described as follows:

a. Acquisition. The upper half (above dotted line) of Figure 2-2 portrays the COMMEL II.5 events in the DF intelligence acquisition process. Sensor intelligence (detection) levels are between 0 and 1. These were converted to plausible DF detection probabilities through application of a curve-fitting processing using scale factors. An input threshold value serves as a detection level cutoff for determining a "good" DF fix on a unit.

The three sensors are located in the Red General Outpost Line (GOP) and operate independently of each other. A sensor scan was performed at 15 minute intervals of game time. In each scan period COMMEL II.5 initially assesses the number of conditional good fixes on a unit. These are based on sensor sensitivity, distance from unit and unit type. For each detected unit, a 'collection center' located at one of the EW units subsequently determines whether it has at least two good fixes. If not, no action or effects result due to insufficient information. The initial fixes are also conditioned on associated electronic emissions. Therefore, in addition to two conditional good fixes, a unit must have generated a message in the scanned radio modes within the past game hour.

b. Intelligence Assessment and Transmittal. The events in this section are reflected in the lower half (below dotted line) of Figure 2-2. The intelligence collection center merges DF intelligence passed by all three EW units during the acquisition phase. The merged intelligence is adjusted so that it is higher for units detected with three fixes than with two. A DF intelligence adjustment is also made on the basis of time elapsed since the last radio transmission from the detected units. A factor denoted by 'Tm Since Last Xmsn' in Figure 2-2 reduces DF intelligence level with increasing time since last transmission.

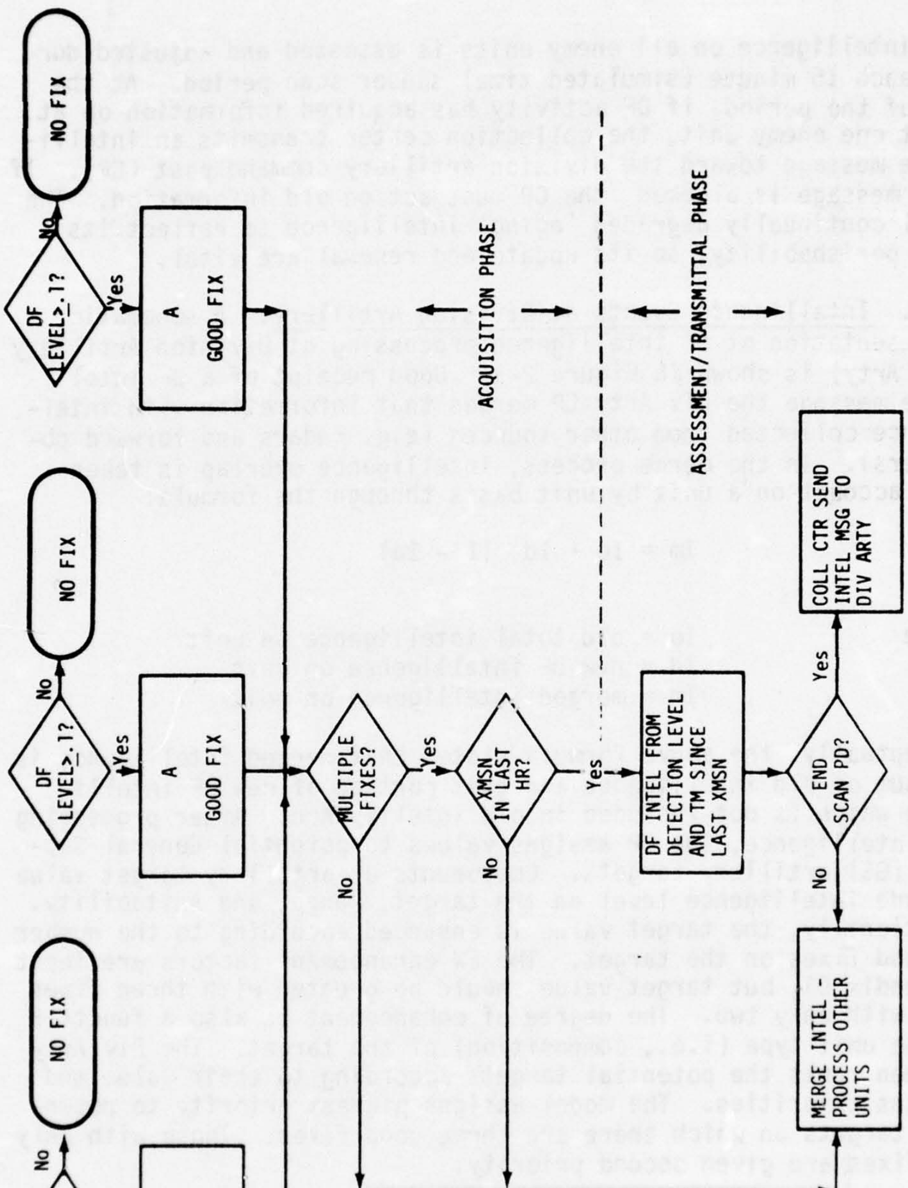

Figure 2-2. DF Intelligence Events - Sensor to Div Arty

The intelligence on all enemy units is assessed and adjusted during each 15 minute (simulated time) sensor scan period. At the end of the period, if DF activity has acquired information on at least one enemy unit, the collection center transmits an intelligence message toward the division artillery command post (CP). If this message is blocked, the CP must act on old information. The model continually degrades 'aging' intelligence to reflect its time perishability, so its update and renewal are vital.

c. Intelligence Events at Division Artillery. A schematic representation of DF intelligence processing at Division Artillery (Div Arty) is shown in Figure 2-3. Upon receipt of a DF intelligence message the Div Arty CP merges that information with intelligence collected from other sources (e.g. radars and forward observers). In the merge process, intelligence overlap is taken into account on a unit by unit basis through the formula:

$$Im = Io + Id\ (1 - Io)$$

where Io = old total intelligence on unit
Id = new DF intelligence on unit
Im = merged intelligence on unit

Conceptually, the above formula states that merged intelligence is the sum of old intelligence and that portion of new DF intelligence which is not included in old intelligence. After processing the intelligence, the CP assigns values to potential General Support (GS) artillery targets. Components of artillery target value include intelligence level on the target, range, and suitability. Additionally, the target value is enhanced according to the number of good fixes on the target. The EW enhancement factors are input (Appendix D), but target value should be greater with three fixes than with only two. The degree of enhancement is also a function of the unit type (i.e., composition) of the target. The Div Arty CP then ranks the potential targets according to their value and assigns priorities. The model assigns highest priority to potential targets on which there are three good fixes. Those with only two fixes are given second priority.

2-5. RATIONALE. The logical event chain described above should produce certain predictable simulation effects. The sensor acquisition rate is range and radio dependent. No DF intelligence is generated if a target unit is silent or out of range. Units in sensor range and transmitting are more likely to be targeted by

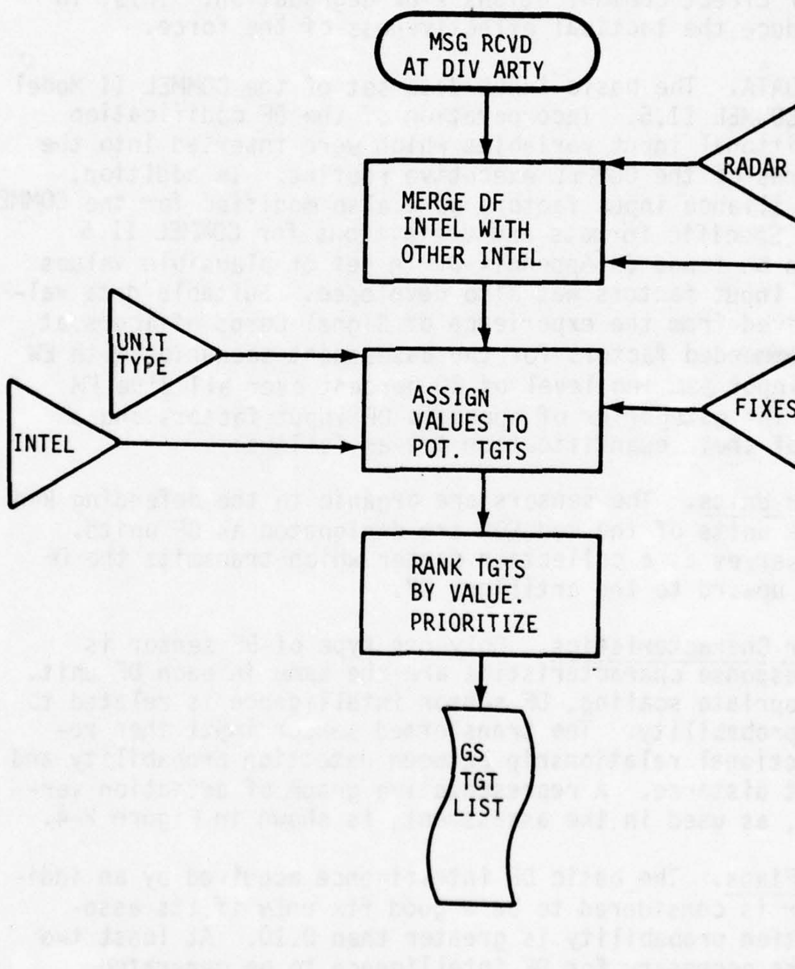

Figure 2-3. DF Intelligence Process at Div Arty

artillery. If struck, these units may suffer extensive damage since artillery damage depends in part on target intelligence which is enhanced by the DF process. The DF contribution is dependent upon the precision of the artillery being at least as good as the precision of the artillery locator. The efficiency of artillery strikes should be increased with added DF intelligence. Movement of target units should also be degraded due to the more effective artillery and the additional intelligence from DF. Performance of the communications system may be degraded depending on the communications links through units which are struck and attrited. If DF is combined with jamming, the targeted force should suffer direct communications link degradation. This, in turn, may reduce the tactical effectiveness of the force.

2-6. INPUT DATA. The basic input data set of the COMMEL II Model was used in COMMEL II.5. Incorporation of the DF modification required additional input variables which were inserted into the parameter cards of the COMMEL executive routine. In addition, certain surveillance input factors were also modified for the COMMEL II.5 Model. Specific formats and definitions for COMMEL II.5 EW inputs can be found in Appendix D. A set of plausible values for these EW input factors was also developed. Suitable data values were derived from the experience of Signal Corps officers at USACAA. Recommended factors for the assessment scenarios with EW included an input jamming level of 30 percent over all Blue FM radio nets. The categories of specific DF input factors and a description of their quantification are as follows:

a. Sensor Units. The sensors are organic to the defending Red force. Three units of the Red GOP are designated as DF units. One of them serves as a collection center which transmits the DF intelligence upward to the artillery CP.

b. Sensor Characteristics. Only one type of DF sensor is used. Its response characteristics are the same in each DF unit. Through appropriate scaling, DF sensor intelligence is related to a detection probability. The transformed sensor input then reflects a functional relationship between detection probability and sensor-target distance. A representative graph of detection versus distance, as used in the assessment, is shown in Figure 2-4.

c. Good Fixes. The basic DF intelligence acquired by an individual sensor is considered to be a good fix only if its associated detection probability is greater than 0.10. At least two good fixes are necessary for DF intelligence to be generated.

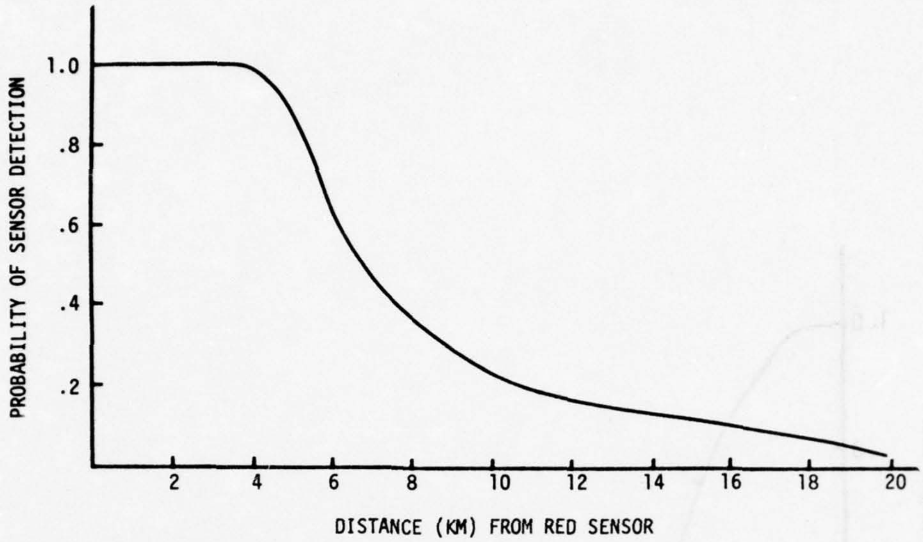

Figure 2-4. Detection vs. Distance - Blue BnCp

d. Intelligence Enhancement and Good Fixes. The DF intelligence confirmed by all three sensors (i.e. with good fixes) is valued 50 percent greater than that determined from only two good fixes. There is no effect from less than two fixes.

e. Intelligence Enhancement and Emitters. No DF intelligence is produced on a target unit which has generated no radio messages for over an hour. When intelligence is produced, its level is affected by the recency of the last radio transmission of the detected unit. There is an intelligence attenuation with age which reflects the perishability of emission information. Figure 2-5 shows the adjustment of DF intelligence with increasing elapsed time since transmission by the detected unit. A dynamic adjustment is possible since the COMMEL II.5 Model maintains a continual record of the time of the last radio transmission from each unit.

f. Artillery Target Factors. Artillery target values are adjusted according to the number of good DF fixes. The value of DF intelligence is only one input in the computation of artillery target value. Target distance, strength and unit type are also components. Targets with three good fixes are valued twice as highly as those with only two if all other factors are equal. The target value can also be varied according to unit type, but all unit types were treated equally in the assessment scenarios.

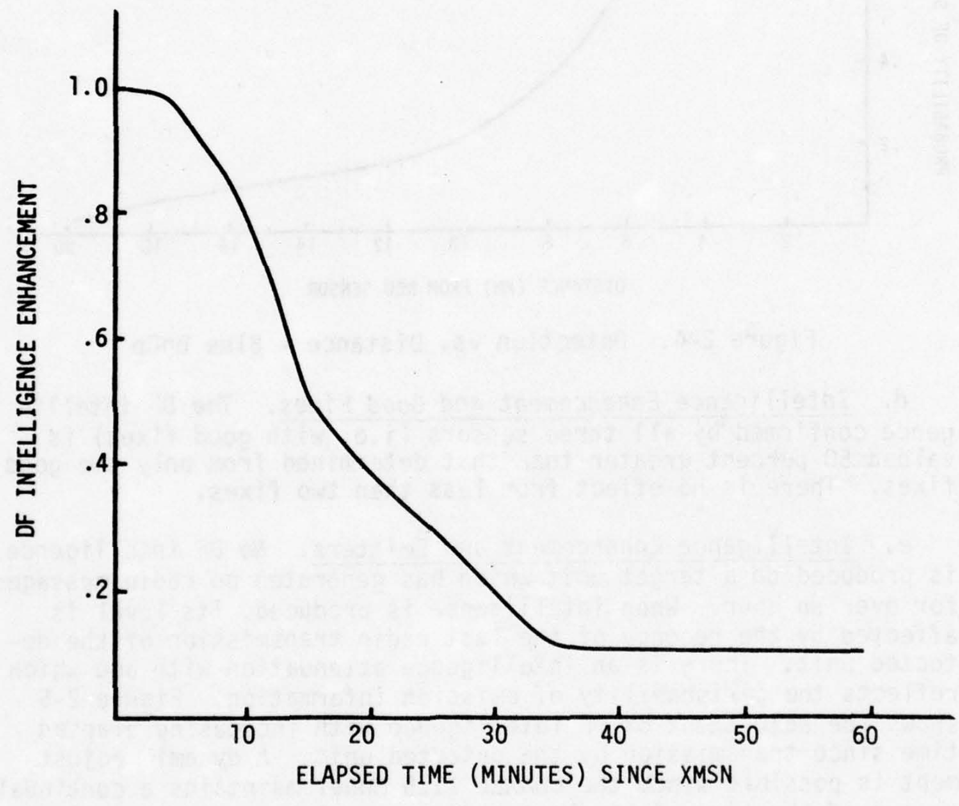

Figure 2-5. DF Intelligence Adjustment for Age of Emission

CHAPTER 3

ASSESSMENT AND EVALUATION

3-1. INTRODUCTION. This chapter describes the assessment of comparative operation of COMMEL II.5 with and without an active Red EW environment. MOP and MOE are applied to determine the extent of the effects of the EW modifications. Limitations on the scope of results and of techniques are also discussed.

3-2. PROCEDURE. a. General. The COMMEL II.5 Model was exercised to determine the variation in model output due to Red EW, (DF intelligence and jamming). Effects were analyzed by comparing selected MOP and MOE extracted from assessment runs with and without EW. Comparative analyses in terms of cause and effect were performed. The scope of the assessment was limited to a gross evaluation of the two scenarios described below.

b. Scenarios. The two scenarios were taken from those used in the USACAA study, Integrated Tactical Communications System (INTACS Alternatives II).* Only the INTACS system was considered, the objective here being the assessment of the effects of EW routines in COMMEL II.5; competing systems are not compared. The basic scenarios used are as follows.

(1) Control Case. A Blue armored division in an attack posture engages in eight hours of combat with a defending Red motorized rifle division.

(2) Red EW Case. The Red EW scenario used the control case scenario with the addition of EW. The Red division operated with three organic DF sensors, each being located in a unit of the GOP. In addition, Red ECM included jamming affecting 30 percent of all Blue radio links.

c. Assessment Measures. In the analysis of communications and force operations, two communications MOP and four combat MOE were used. Cumulative combat statistics were tabulated.

(1) Communications MOP. The following MOP were used to evaluate the effect of EW on Blue communications system performance.

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*op.cit.

(a) Number of Blue Units with Good Fixes. In the context of an EW scenario, this measure quantifies the extent of coverage of the Red DF system and conversely the vulnerability of Blue communications. It is a first order MOP and cannot be related directly to combat outcome. This MOP has no meaning in the control (No EW) scenario.

(b) Number of Blue Message Failures. The second order impact of EW on communications is assessed by this MOP. Model input parameters set deadlines that determine the maximum allowable message transit time for delivery for each message type. If a message is not delivered by the deadline time for any cause, the message is counted as failed. Degradation of the Blue communications system due to EW should be reflected in increased frequency of message failure. This MOP is given in the context of total messages generated so that a percent failure can be assessed.

(2) Combat MOE. The following MOE were used to evaluate the impact of EW operation on Blue force combat outcome. Since these can depend on deployment status, Blue statistics were separately computed for battalions deployed in reserve and in committed status.

(a) Blue Progress Toward Objective. This MOE measures the progress made by Blue battalions advancing toward tactical objectives. The progress along a straight line from the lead unit position of each battalion to the center of the battalion objective was measured as a percentage of the initial distance (from the line of departure (LOD)) to the objective.

(b) Blue Battalion Move Rate. This MOE measures the average rate of progress (km/hr) of attacking Blue battalions along a line from the LOD to their tactical objectives. The MOP was calculated by partitioning the battalion path from the LOD to the objective into segments, each of which represented one hour of travel.

(c) Number of Blue Personnel Attrited. This MOE is the total personnel lost by Blue forces during each period simulated.

(d). Number of Red Artillery Strikes. This MOE is the total number of Red (General and Direct Support) artillery strikes initiated during the period simulated. All strikes fired were counted, regardless of the resulting effectiveness of the strike.

d. Definition of Cumulative Sum. Most of the combat MOE are tabulated at the end of each simulated combat hour. An overall summary statistic was developed. A simple average over hours was

not meaningful since the tabulated values generally represent cumulative status at the end of each hour. The area under the bar graph of status versus elapsed time was more useful. This measure was defined as the 'cumulative sum' for that MOE. In the cases herein, the (time) spacing between bar chart ordinates was one game hour. Therefore, the corresponding cumulative sum is equivalent to the sum of the ordinates (status values). However, it should be regarded as dimensionless and as an unnormalized area (unnormalized since its magnitude depends on the ordinate scale). The measure does have utility when interpreted as an 'area under the curve'. The 'curve' is that implied by the continuous graph representation of any of the bar charts shown. Figure 3-1 illustrates the concept of cumulative sum as derived from a bar chart. For a cumulative status chart, a large value of the cumulative sum can be due to multiple influences. It could reflect a large status change from one hour to the next. However, the same effect results from a moderate status change occurring at an early hour. Therefore, the statistic is influenced by both the magnitude and timing of a change in battalion state. The cumulative sums were computed over four and eight simulated combat hours in the scenarios studied.

e. Sampling Considerations. The COMMEL II.5 Model has stochastic processes in the communications failure and repair algorithms and in the allocation of background message traffic. Therefore, some random variation in model results is expected from runs using the same scenario with different random number 'seeds'. Three replications differing only in random 'seed' were executed from both the control and the EW scenario. The arithmetic average of results for each scenario was used in the computation of MOP and MOE.

f. Statistical Tests. The differences in MOP and MOE alone were not reliable indicators of statistical significance. A standard t-test was used to assess the significance of differences between the control and Red EW cases. Six data points were used in the statistical formula for each test, i.e., the values from the three replications for each case were used individually in the determination of significant differences. The highest significance level associated with each MOE comparison was determined and is tabulated.

g. Battalion State. A broad analysis of preliminary model results indicated that small but consistent differences were observed between units initially in committed and in reserve status. Therefore, combat results were separately tabulated for a battalion in each state.

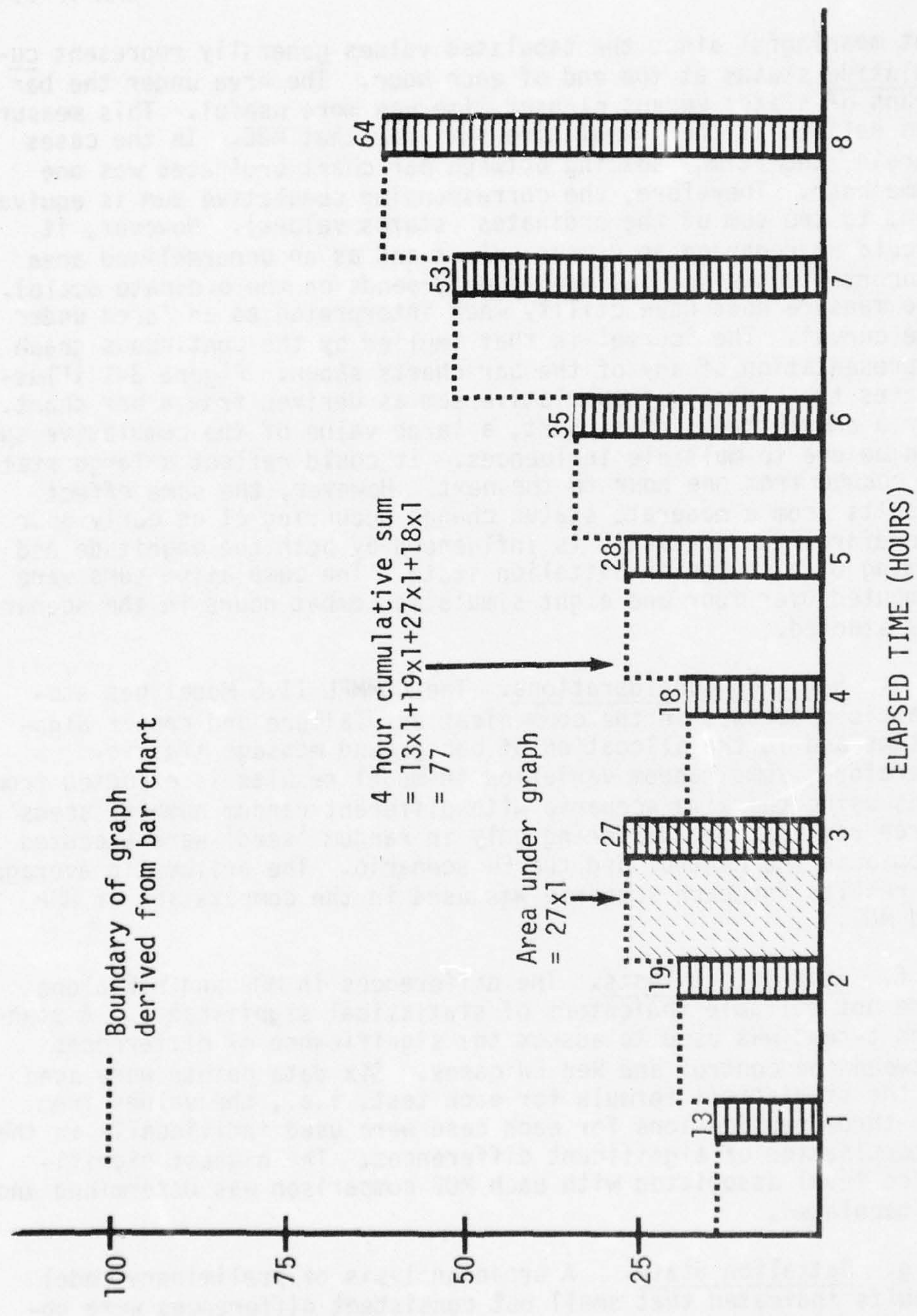

Figure 3-1. Concept of Cumulative Sum - Illustrative Example

3-3. ANALYSIS OF COMMUNICATIONS RESULTS. a. Number of Fixes. Table 3-1 shows the incidence of 1, 2 and 3 good fixes acquired by the Red DF system in the EW scenario. The total number of Blue units with 1, 2 or 3 good fixes is 28 in the first hour. The figure rises to 35 at the fourth hour and decreases to 18 by the eighth hour. These results plausibly reflect the tactical movement of the scenario. Since the sensor units are in the Red GOP, they are initially near the FEBA. Therefore, their initial acquistion rate is substantial and their coverage is broad. By the fourth hour, the Blue front line units have contacted or broken through the Red main line of defense. At that time, the Red GOP is retrenching toward rearward positions where their facilities will be reestablished. Overall contact is more intense than at the start. The result is an overall rise in DF fixes. However, since the retrenching GOP is no longer optimally deployed for reconnaissance, the breadth of coverage is reduced. Therefore, there are fewer incidents of three good fixes (12 versus 27 at the first hour). As the battle progresses, total sensor acquisitions are reduced as the GOP moves in stages toward reestablished positions out of the path of the main Blue advance. In summary, the DF results are consistent with the changing state of combat and enhance model credibility.

Table 3-1. Number of Blue Units with 1, 2 and 3 Good DF Fixes

	Number of Good Fixes		
Hour	One Fix	Two Fixes	Three Fixes
1	0	1	27
4	6	17	12
6	7	11	7
8	3	10	5

b. Message Failures. Table 3-2 shows the message failure incidence for both scenarios. The failed Blue messages generated from line units are differentiated from those generated by support units (background traffic). The EW scenario produced over 50 percent more total message failures than the control. This difference is significant at the 0.01 level. Since considerably fewer messages were generated in the EW case, the difference in percent failed is even larger. The increased failures result from a combination of jamming and increased vulnerability of equipments from improved Red targeting due to DF intelligence. The increase in message failures under EW is small for support units. However,

the front line units incur over 100 failures in the EW case but virtually none in the control. Most of the line unit message failures were Blue intelligence messages. This result reflects the increased susceptibility of the Blue front line units to attrition and ECM. Several factors are responsible. First, these units are in close contact with the Red forces. Secondly, most of the division radios affected by ECM and sensed by DF are in these units. In summary, the failure statistics are consistent with the structure and operation of the tactical communications system.

Table 3-2. Number of Blue Message Failures After 8 Hours of Combat

Scenario	Total Fails	Total Msgs	Line Unit Fails	Spt Unit Fails
Control	241	4,760	1	241
Red EW	382	4,110	104	278

3-4. ANALYSIS OF COMBAT RESULTS. a. General. The results presented in this section are for a Blue division on the offense against a defending Red motorized rifle division. All but one MOE reflect Blue status. Use of Blue force statistics directly reflect active Red EW effects. In addition, the Red force is in a defense posture and has a primary mission of stopping Blue attacker progress. Therefore, success of the Red force can be measured through its degradation of the Blue attack mission. One statistic of Red status--the number of Red artillery strikes--is presented as a means of assessing the effect of the DF system on artillery utilization.

b. Tactical Outcomes

(1) Blue Progress Toward Objectives. Figures 3-2 and 3-3 show Blue progress toward objective with and without Red EW for a committed and a reserve battalion respectively after 4, 6 and 8 simulated combat hours. The corresponding cumulative sums (as defined in paragraph 3-2d.) and the statistical significance of differences between the control and the EW cases are shown in Tables 3-3 and 3-4. The trend of all statistics is consistent with the pattern of battle. After an initial advance, contact with the GOP slowed Blue progress from the first to the second hour. After penetrating the GOP, the Blue advance accelerated until it encountered the main Red defense line between the fourth and fifth hours. Subsequently, progress picked up until Blue units reached

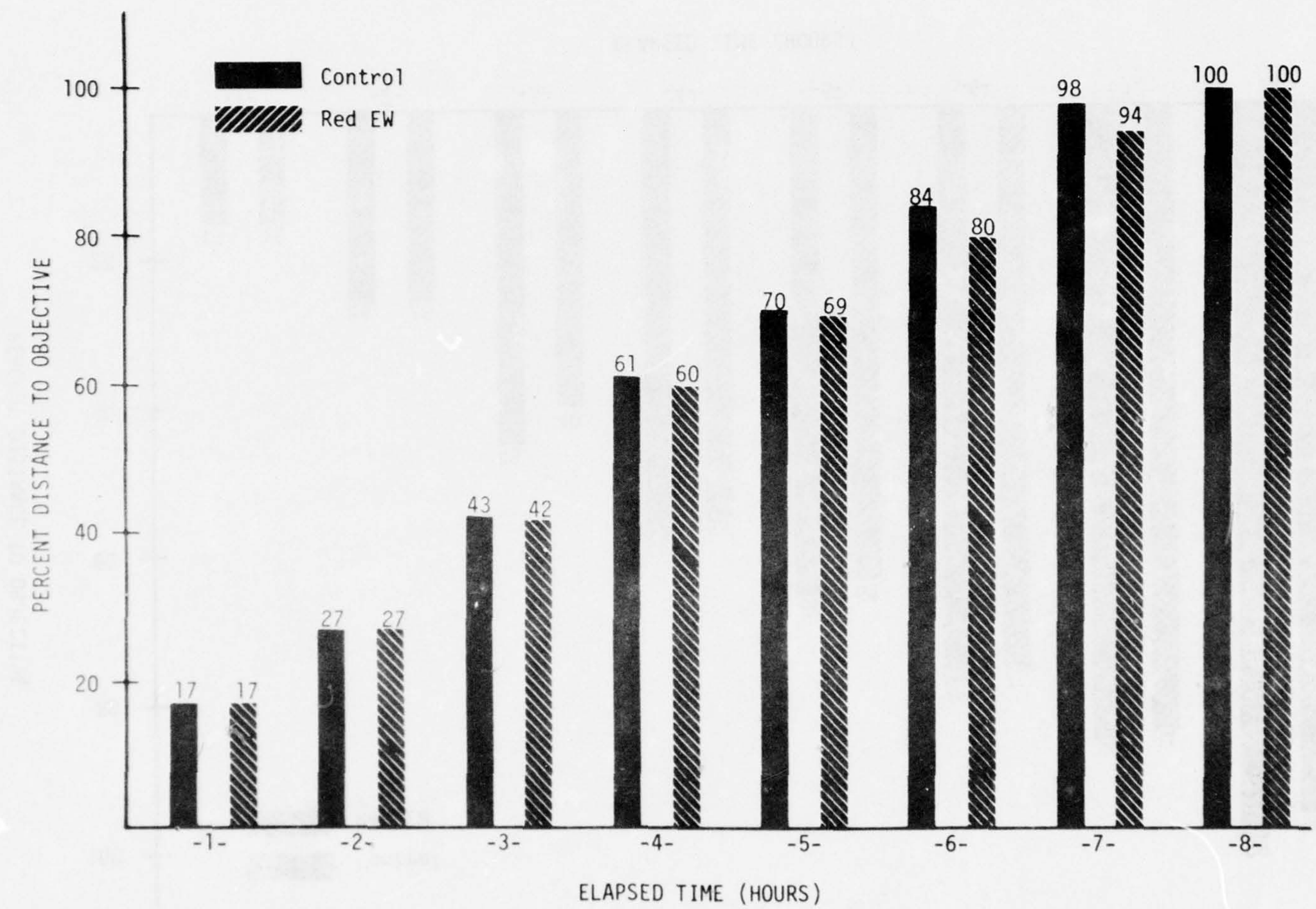

Figure 3-2. Blue Progress Toward Objective - Committed Bn

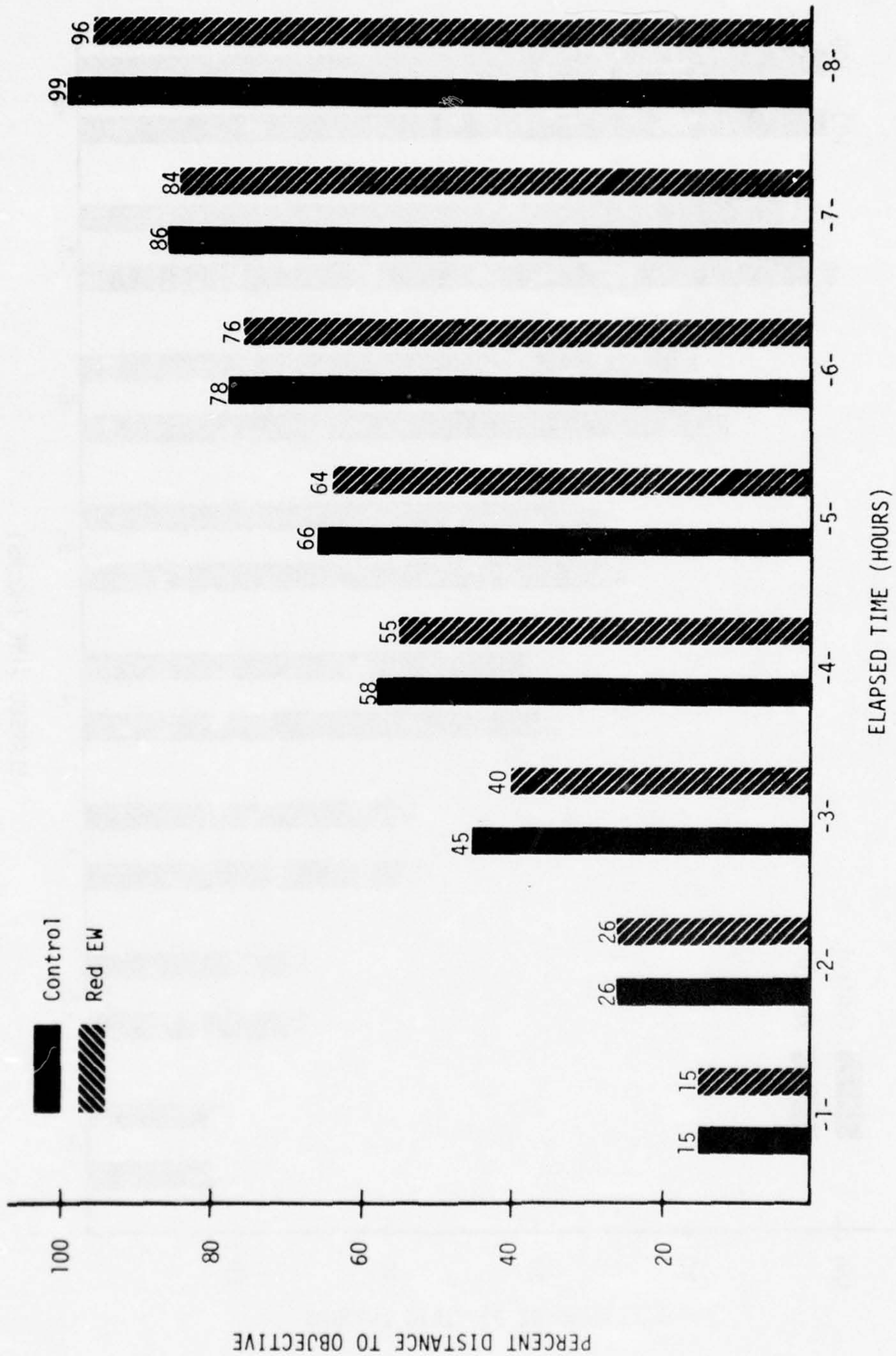

Figure 3-3. Blue Progress Toward Objective - Reserve Bn

the final assault line near the objective in the seventh or eighth hour. The pattern is similar for both the committed and the reserve battalion, but the latter generally lagged the committed force. The Blue advance under Red EW is generally less than in the control scenario. The cumulative sums show that overall Blue progress is reduced under EW. This effect is due in great part to improved Red intelligence and targeting from the DF system as well as to degradation of Blue communications links by Red ECM. The ECM will reduce Blue intelligence and maneuver effectiveness. The overall results are compatible with the logical impact of the EW environment on the observed flow of battle events.

Table 3-3. Cumulative Sum - Blue Percent Distance To Objective - Committed Bn

	Hour		
Scenario	4th	6th	8th
Control	147.50	301.50	499.5
Red EW	146.00	295.00	489.0
Significance	0.25	0.025	0.05

Table 3-4. Cumulative Sum - Blue Percent Distance to Objective - Reserve Bn

	Hour		
Scenario	4th	6th	8th
Control	144.	288.	473.
Red EW	136.	276.	456.
Significance	0.005	0.005	0.025

(2) Blue Move Rate. Figures 3-4 and 3-5 show the Blue move rate toward objective with and without Red EW for a committed and reserve battalion respectively. The associated cumulative sums are shown in Tables 3-5 and 3-6. The statistics reflect the changing status of battles. An initially high Blue move rate is reduced upon encountering the Red GOP in the second hour and the main Red defense force in the fifth hour. The rate for the reserve battalion tends to be higher than for the committed battalion. The difference may reflect the lesser resistance (relative to line units) encountered by the reserve. While there is considerable variability, the overall move rate as measured by the cumulative sum is reduced by Red EW for both the committed and the reserve battalion. A seeming inconsistency appears in the eighth hour on the chart for the committed battalion (Figure 3-6). In that instance, the Blue move rate under Red EW is 60 percent greater than that without EW. The explanation is that the Blue battalion was very close to its objective by the seventh hour in the control case. This is apparent from Figure 3-2. Further significant progress was blocked since a battalion "digs in" at its objective. Under Red EW, however, the degraded Blue progress during the first seven hours left a greater battalion 'distance to objective' over which to travel. Thus, the apparent inconsistency reflects model rules more than combat effects. On an hourly basis the largest difference between Blue move rates with and without Red EW generally occurred following a period of heavy resistance. In the committed battalion after penetration of the Red main defense line in the fifth hour, the move rate under EW was 16 percent less than in the control case. For the reserve battalion, the Blue move rate under EW after contacting the Red GOP in the second hour was 26 percent less than in the control. These results are plausible since a period of heavier force contact frequently generates more DF intelligence and targets for the Red force. While the overall differences are small, they are generally statistically significant and consistent with the underlying tactical activities.

Table 3-5. Cumulative Sum-Blue Move Rate-Committed Bn

	Hour		
Scenario	4th	6th	8th
Control	24.9	34.1	42.2
Red EW	24.4	32.1	41.2
Significance	0.20	0.05	0.10

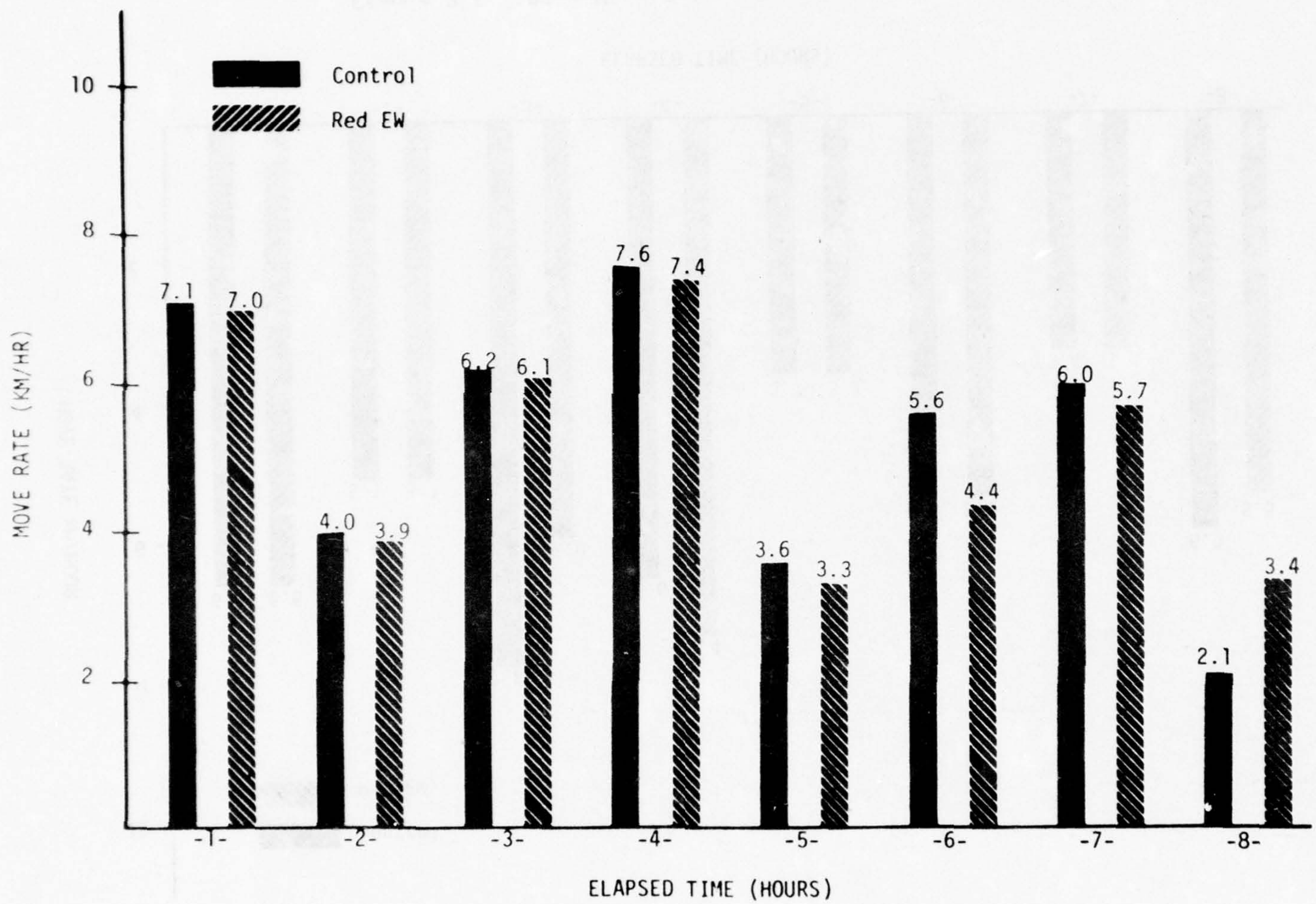

Figure 3-4. Blue Move Rate - Committed Bn

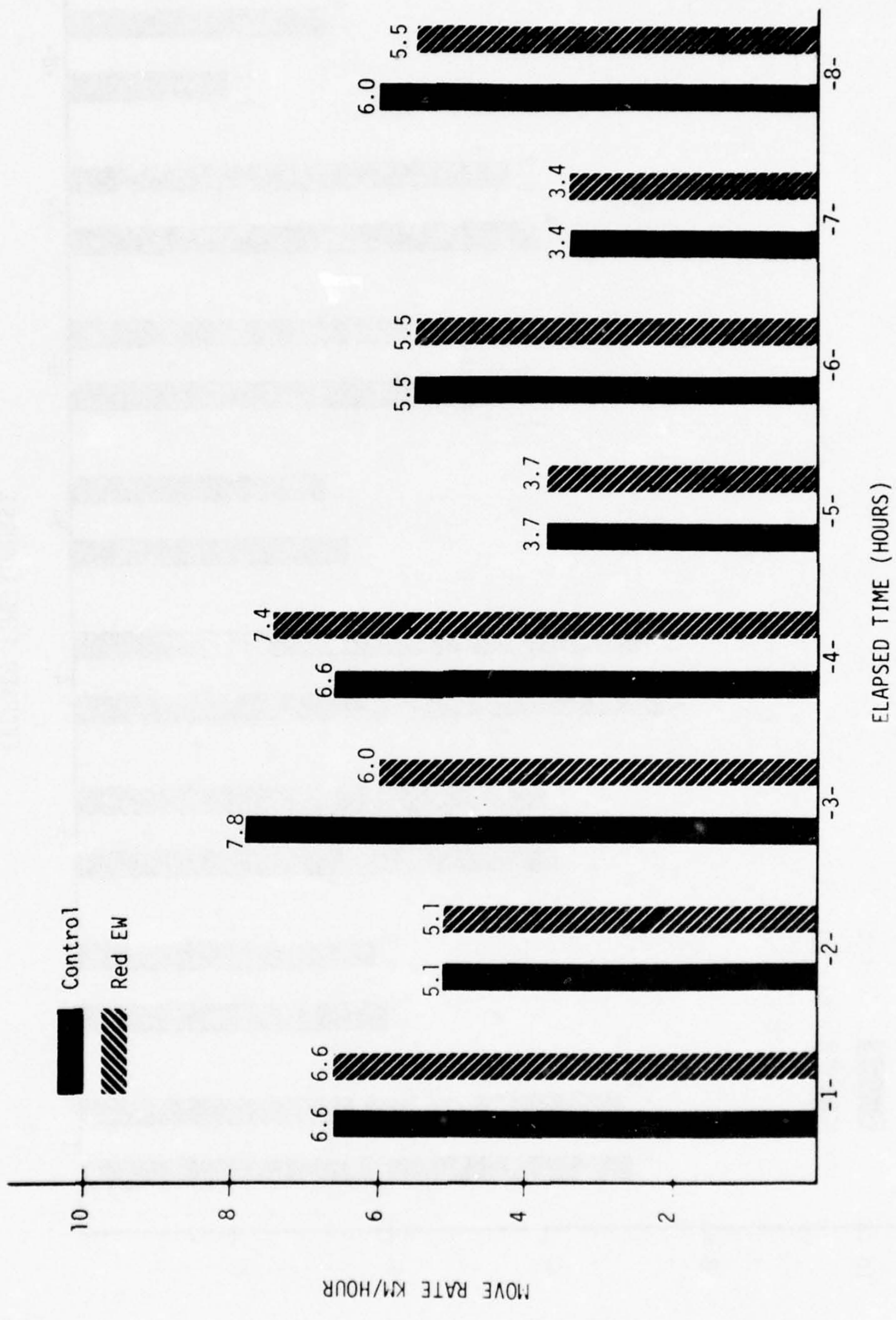

Figure 3-5. Blue Move Rate - Reserve Bn

Table 3-6. Cumulative Sum-Blue Move Rate-Reserve Bn

	Hour		
Scenario	4th	6th	8th
Control	26.1	35.3	44.7
Red EW	24.5	34.3	43.2
Significance	0.025	0.005	0.10

(3) Number of Personnel Attrited. Figures 3-6 and 3-7 show the number of Blue personnel attrited by hour, with and without Red EW, for a committed and a reserve battalion, respectively. The associated cumulative sums and significant levels are shown in Tables 3-7 and 3-8. In all cases the Blue attrition became heavy only after the Red main defense line was engaged in the fifth hour. The integrated sums show that the EW scenario resulted in more overall Blue attrition than the control.* For both the committed and reserve battalions the largest relative difference occurred in the fifth hour. The increased casualties under Red EW in that hour are partly due to the peaking of Red DF intelligence under circumstances where it could be effectively used. These included close contact by the Red main defense line. The peaking of Red DF intelligence between the 4th and 5th hour is evident in Table 3-1 which was discussed earlier. The jamming aspect of EW contributed to the degradation of Blue intelligence communications links and their products. The lessened intelligence tended to reduce Blue force effectiveness and increase overall attrition.

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*A side observation is that personnel attrition of the committed Blue bn in the Red EW case after the fifth hour is considerably less than that of the reserve bn. This effect is due to the assumption of decreased artillery vulnerability of the front line Blue bn after penetrating beyond the Red main defense line during the fifth hour. At that time higher Red targeting priority was allocated to the lagging Blue reserve bn as the primary threat. The Red EW increased artillery effectiveness by reducing target error.

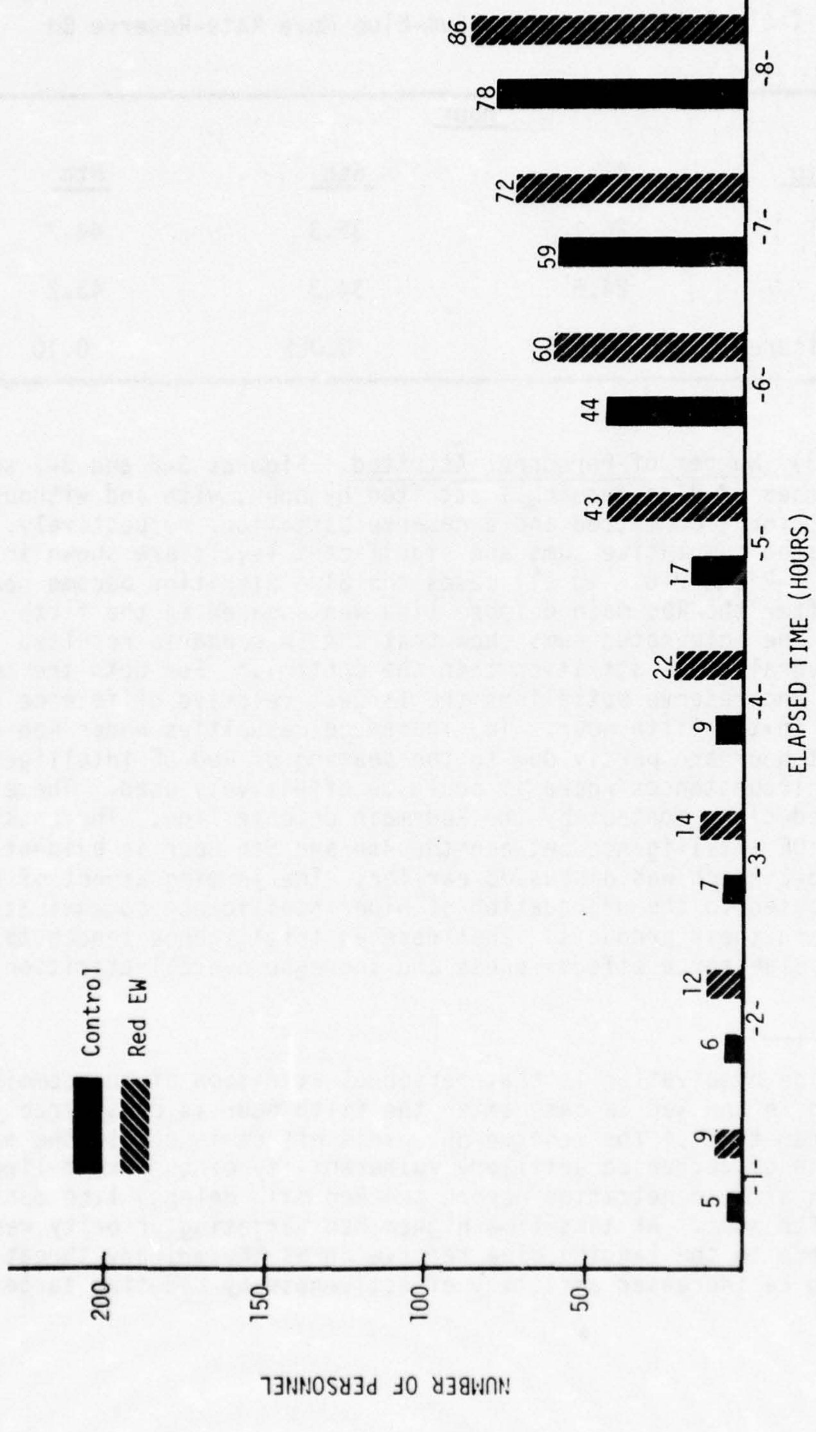

Figure 3-6. Number Blue Personnel Attrited - Committed Bn

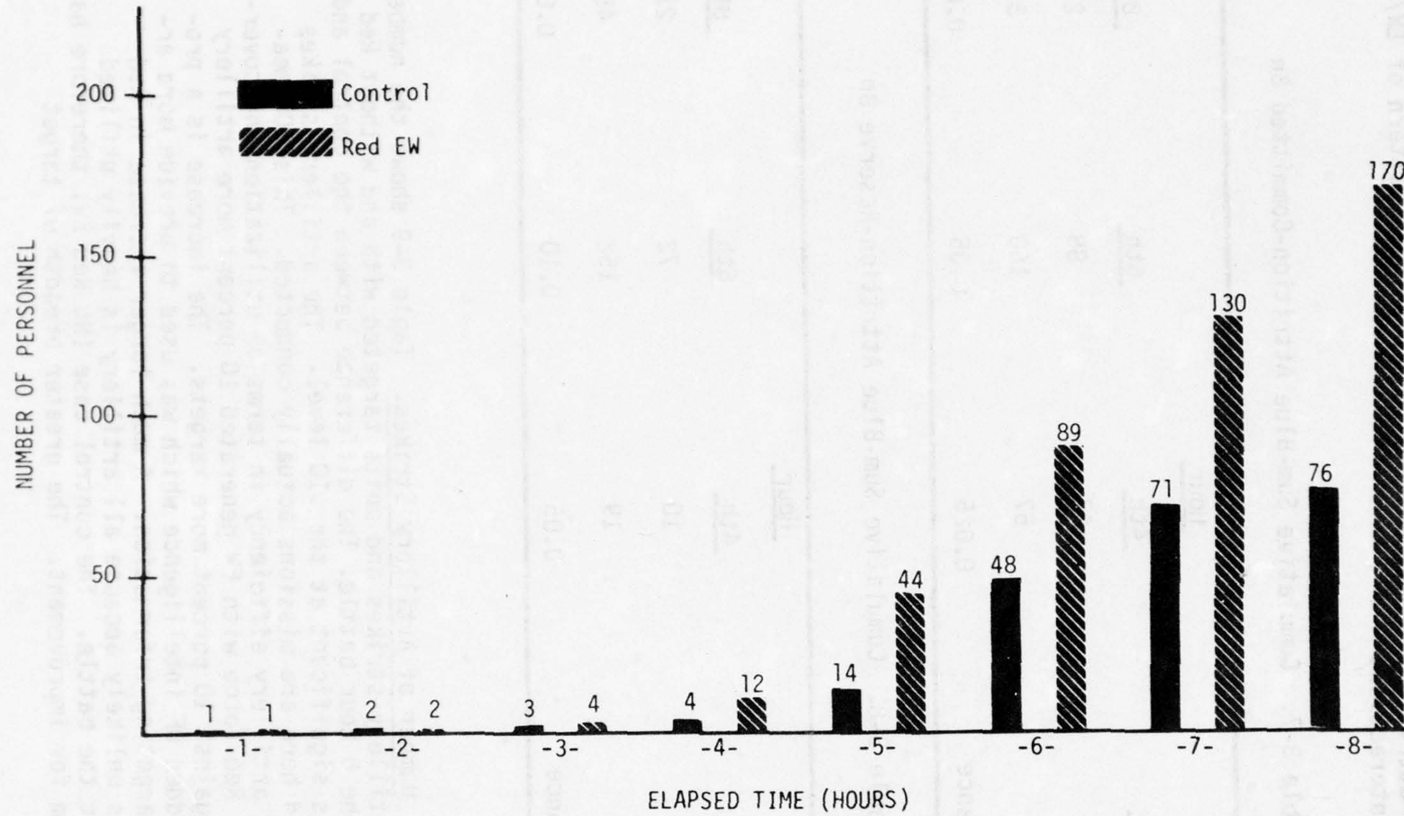

Figure 3-7. Number Blue Personnel Attrited - Reserve Bn

While there is considerable variation on an hour-by-hour basis, the Blue attrition results conform to a plausible pattern of EW/combat interaction.

Table 3-7. Cumulative Sum-Blue Attrition-Committed Bn

	Hour		
Scenario	4th	6th	8th
Control	27	88	225
Red EW	57	160	318
Significance	0.025	0.05	0.07

Table 3-8. Cumulative Sum-Blue Attrition-Reserve Bn

	Hour		
Scenario	4th	6th	8th
Control	10	72	229
Red EW	19	152	452
Significance	0.05	0.10	0.05

(4) Number of Artillery Strikes. Table 3-9 shows the number of Red artillery strikes and units targeted with and without Red EW over the 8 hour battle. The difference between the control and EW case is significant at the .10 level. The artillery strikes summarized here are missions actually conducted. This MOE measures Red artillery efficiency in terms of utilization and coverage. The Red force with EW generated 10 percent more artillery strikes against 10 percent more targets. The increase is a product of added DF intelligence which was used to provide more artillery targeting information. A much larger increase in Red strikes is unlikely because all artillery is heavily utilized throughout the battle. The control case (No Red EW) therefore has small room for improvement. The greater breadth of target

coverage under Red EW reflects the selection of targets which would not be included without the added DF intelligence. The overall results for this MOP are consistent with the expected operation of the Red EW system.

Table 3-9. Number of Red Artillery Strikes

Scenario	Red Arty Strikes	Units Targeted
Control	140	41
Red EW	154	45
Significance	0.1	0.1

CHAPTER 4

OBSERVATIONS

4-1. ANALYTIC POTENTIAL. The COMMEL II.5 Model has demonstrated the potential for comparative analysis of simulated division combat with and without EW. Force effectiveness can be measured through statistics on changes in combat status and in communications system performance. The following specific observations resulted from verification testing of the COMMEL II.5 Model. These tests used a control scenario with no EW and an EW scenario with both Red DF and jamming.

a Blue Communications Performance. The comparative results showed that the DF system acquired substantial intelligence and that the pattern of acquisitions conformed to the movement of forces. The DF intelligence acquisitions peaked at periods of intense force contact. The increased incidence of Blue message failures under Red EW was statistically significant and was shown to reasonably reflect the effects of Red EW. There were more message failures under Red EW and these were concentrated in the front line units.

b. Blue Combat Performance. The Blue force under Red EW was impeded in its progress toward objectives. While the differences were small (2-6 percent), most were statistically significant at the .05 level or better. The pattern of Blue force movement and the timing of significant slowdowns under Red EW were consistent with concurrent combat events. Results indicated that the impact of Red EW was greater in periods of intense force contact. The Blue attrition under Red EW was greater than in the control case. Most of the associated differences were significant at the .07 level or better. The pattern and timing of variations in attrition were associated with the changes in battle state. The results demonstrated the logical and plausible interaction of the simulated EW effects in the overall context of battle.

c. Red Combat Performance. Red artillery utilization and coverage increased about 10 percent under Red EW. This improvement was statistically significant at better than the 0.10 level. This result is compatible with the designed function of the DF simulation process to provide more intelligence for artillery targeting.

4-2. MODEL IMPROVEMENT. The intelligence intercept capability of signal intelligence (SIGINT) has not been fully modeled. The COMMEL II.5 Model does simulate the direction finding and artillery

target referral capabilities. However, the model should be extended to include a broader representation of intercept intelligence. The EW process should be applicable to either/both the Red or Blue force with each operating in a detailed communications environment. Currently, the full EW process is adaptable only to the Red force which operates with a 'perfect' communications system.

APPENDIX A

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1. STUDY TEAM

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MAJ James H. M. Malley, Force Concepts and Design Directorate

Mr. Martin Dwarkin, Systems Force Mix Directorate

APPENDIX B

GLOSSARY

Bn	battalion
COMMEL II	A division-size ground combat/communications simulation which relates combat action to communications system effectiveness
COMMEL II.5	An updated version of COMMEL II which incorporates aspects of EW including direction-finding
CP	command post
DCSOPS	Deputy Chief of Staff for Operations and Plans
DS	direct support
DF	direction-finding
Div Arty	division artillery
ECM	electronic counter measure
ESM	electronic warfare support measures
EW	electronic warfare
FEBA	forward edge of the battle area
FM	frequency modulated
GOP	general outpost line
GS	general support
INTACS	Integrated Tactical Communications System
km	kilometer
LOD	line of departure
MOE	measure of effectiveness
MOP	measure of performance

SIGINT	signal intelligence
TRADOC	United States Army Training and Doctrine Command
USACAA	United States Army Concepts Analysis Agency

APPENDIX C

THE COMMEL II MODEL

C-1. OVERVIEW. The Communications-Electronics II (COMMEL II) Model is a computerized combat simulation which dynamically integrates communications and combat operations. The basic battle simulation is at division level with resolution to company level. The model consists of four submodels: the tactical submodel, the communications submodel, the background traffic submodel, and the message processor submodel. Figure C-1 shows the relationships between the submodels. The submodels operate interactively and dynamically, and transmit event statistics to the output file where results are recorded periodically throughout the simulation. The functions of each submodel are described below.

a. The Tactical Submodel. This submodel simulates the conduct of tactical combat. Tactical activity progresses in essentially the same manner as in many other combat simulation models in which unit movement and attrition are driven by force ratios developed from weapons firepower values. The tactical submodel presently has a capacity for a combined total of 257 Red and Blue units. Six general support (GS) and six direct support (DS) artillery units are included in the 257 units; three GS and three DS units must be assigned to each force. Ten types of units, e.g., tank, infantry, artillery, can be simulated. The COMMEL II Model permits the representation of up to 12 types of weapons on each side. This permits a valid representation of combat capabilities of the two opposing forces. Basic features of the tactical submodel include terrain constraints, unit commitment and associated movement rules, effects of indirect and direct fire, and fire allocation logic. Command decisions and other key tactical data are generated in the tactical submodel and are subsequently transmitted as messages through the simulated communications system. The tactical submodel also generates combat damage to the communications system.

b. The Communications Submodel. The communications submodel determines the status of the division communications system based on input data and combat information from the tactical submodel. Among the factors considered are equipment characteristics, mechanical failure, combat damage, and equipment repair time. COMMEL II simulates jamming of Blue radio nets; the specific nets to be jammed and the level of jamming can be varied in accordance with the study scenario.

c. The Background Traffic Submodel. This submodel interacts with the message processor submodel by inserting additional messages into the simulation to supplement those generated by the tactical submodel. These messages represent a communications traffic level present in actual situations, but not otherwise specifically generated by the COMMEL II Model.

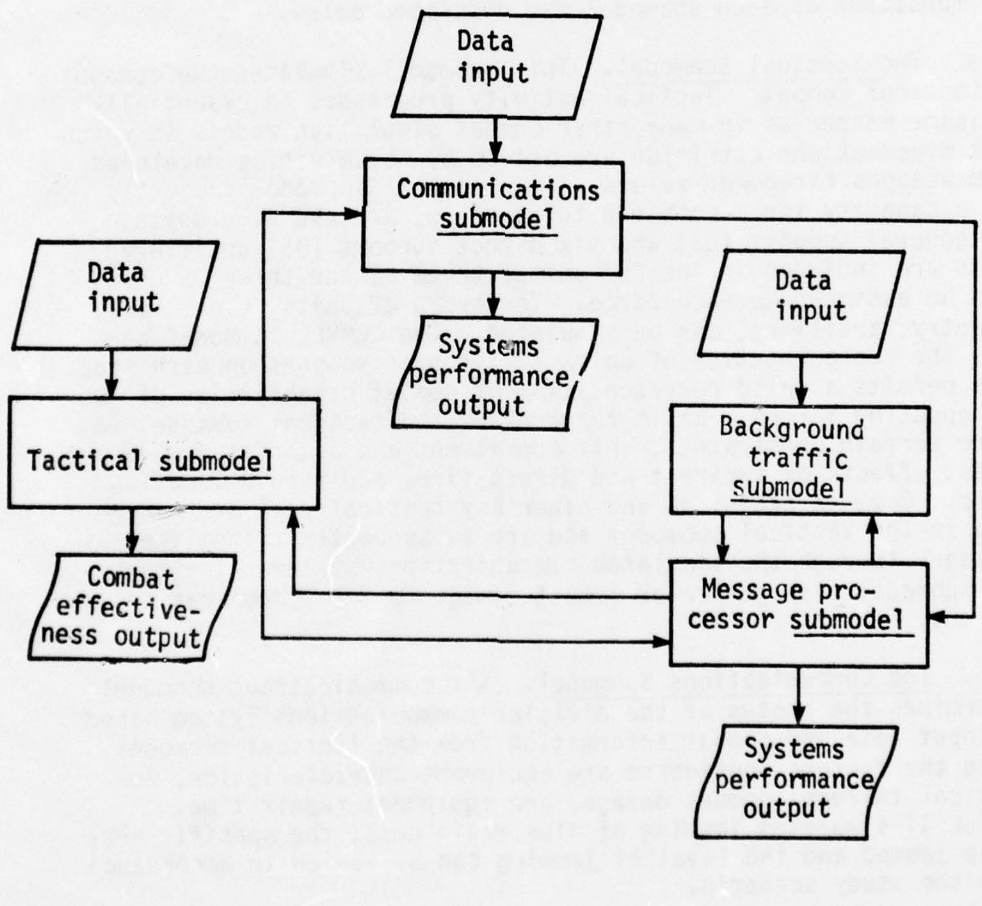

Figure C-1. COMMEL II Submodel Interrelationship

d. The Message Processor Submodel. This submodel simulates the processing of the messages generated by the tactical submodel. The message processor submodel determines if each individual message will be transmitted without delay or with delay, or if it will fail entirely. The identity of each message is maintained in the submodel according to sender, receiver, length, content, communications net used, security, and precedence. Encrypting and staffing delays are modeled. Background messages compete with messages generated by the tactical submodel, with the status of the communications system (supplied by the communications submodel) impacting on processing time, and with the availability of required communications. Message failure or delay may result from various causes, such as technical limitations, e.g., radios out of range, overloaded communications nets, combat damage, and equipment failure. The message processor completes the simulation loop within COMMEL II by sending the message on to the tactical submodel. As messages are delivered, combat operations respond according to the context of the simulated messages. Messages which fail to reach addressees have no opportunity to impact on combat operations, which continue without benefit of the command decisions, target intelligence, or other information contained in the messages.

C-2. INPUT DATA REQUIREMENT. Data requirements for the COMMEL II Model are extensive; on the order of 60,000 data items are needed for a complete data base. This data set is subdivided into several sections: tactical data, communications data, and background traffic data. Each section is discussed below.

a. Tactical Data. Factors describing firepower, development, objectives, intelligence, artillery, messages, terrain and commit decision are input. The message factors here refer to tactical combat messages triggered by dynamic model events. The terrain is characterized by mobility and concealment ratings. Direct fire weapons are assigned "combat values" and nominal ranges.

b. Communications Data. Communications equipment and link characteristics are input to the model. Equipments are assigned vulnerable areas, failure rates, repair rates and ranges. Communications links are described by type, capacity, security class, traffic handled (e.g., intelligence), susceptibility to outages from unit movement, and queuing discipline.

c. Background Traffic Data. These data described tactically related messages which form a basic load on the communications system. These requirements are in the form of needlines, i.e., who talks to whom on a routine basis.

C-3. OUTPUT. A large quantity of output is accessible through disc, tape or printer. The complete communications and message histories are retrievable. Periodic plots of unit locations can be generated. The attrition for each unit and for each force (Blue, Red) is printed at designated intervals. Artillery strike results are printed as they are simulated. Reports on EW coverage can be printed on an hourly basis. The detailed chronological status histories on disc or tape can be post processed to yield a variety of summary statistics.

APPENDIX D

INPUT STRUCTURE IN COMMEL II.5

D-1. GENERAL. Most of the input data and formats for COMMEL II.5 are the same as those found in COMMEL II. The latter are documented in the COMMEL User's Manual.* There are four types of input data: tactical, communications, background traffic and parameter cards. As noted in Appendix D, each of the first three types is passed through its associated preprocessor prior to being used by the simulator. The parameter cards are read into the simulator and contain information on game timing parameters, output options, communications options and jamming. The EW data of COMMEL II.5 were incorporated into the parameter cards and the tactical input of COMMEL II. The data sets for communications and background traffic were left unchanged.

D-2. TACTICAL DATA MODIFICATIONS. Only two of the 37 tactical data input blocks were reconfigured for COMMEL II.5. These were blocks EG and LB. Together, they define characteristics of surveillance devices. The seventh category of block EG has been reserved for defining an EW sensing device in COMMEL II.5. The overall block structure is described in the COMMEL II User's Manual. Data block LB describes units possessing surveillance devices. In COMMEL II.5 the first six units of the block are reserved for EW units using DF. Only the first two records of the block are affected. The rest of the block is unchanged from that descibed in the COMMEL II User's Manual.

D-3. CALIBRATION OF EW DATA. The "base intelligence generation rate," or "base rate(I)," for unit type I, input in columns 62-69 of block EG must be chosen according to the following procedure. First, a representative strength in terms of combat value must be input for each enemy unit type in columns 6-13 of block EG. For each enemy unit type I with strength STH(I) compute:

SUR(I) = "base rate(I)"x4/[STH(I)x(1. - "base rate(I)")]

Then, for a sensor-target separation distance of D km, the DF intelligence level from a transmitting target of type I with current strength (combat value) CURR(I) is:

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*US Army Concepts Analysis Agency, "COMMEL II User's Manual" Volume II - Input Data Preparation," CAA-D-76-6, Oct 76.

$$INT(I,D) = [CURR(I)\ SUR(I)]/[CURR(I)\ SUR(I) + 4D^2]$$

If CURR(I) is set equal to STH(I), then the value of "base rate(I)" should be selected so that INT(I,D) represents a reasonable intelligence-distance relationship. The implied curve may be scaled by a constant factor.

D-4. PARAMETER CARDS. Most of the new EW input factors are read through the parameter cards. Six new parameter cards were added in COMMEL II.5 to those already in use in COMMEL II. The structure and format of the complete set of COMMEL II.5 parameter cards are given below. The listed order of these cards is that required for direct input into the model. Elaboration on parameter card structure as used in COMMEL II can be found in the COMMEL II User's Manual.

COMMEL II-5 Parameter Cards

These variables, read in at execution time, determine options for running of the simulator. Following is a description of the input cards with a definition of each parameter.

Card 1

Col.	Name	Format	
1		II	"1"
5-12	SIMID	A6,A2	Six character run identifier
16	KSAMPL	A1	Game option: 1 = tactical play only, 2 = Red and Blue commo play (not operative on the UNIVAC 1108 version), 3 = Blue commo play, 4 = Red commo play
20-23	PSTART	I4	Game start time (in minutes). Set to "0"
27-30	KGSTOP	I4	Game stop time (in minutes)
34-35	KOMPER	I2	Time (in minutes) between restart dumps

39	NTACT	I1	0 or blank - no translation done, 1 = translate binary tactical output. Set to "0"
51	NREAD	I1	1 = Unit names read from cards 2 = Unit names read from disk file 3 = Unit names not translated Set to "2" for UNIVAC 1108 runs

Card 2

Col.	Name	Format	
1		I1	"3"
6-10	DCRMT1	F5.3	Frequency of translation for selected tactical arrays.
13-17	DCRMT2	F5.3	Number of messages over which to take moving average for STM performances
20-24	DCRMT3	F5.3	Number of minutes in current period
27-31	DCRMT4	F5.3	Base factor used in STM impact calculation
34-38	DCRMT5	F5.3	Minutes over which to compute moving average
41-45	FCRMT6	F5.3	Weighting factor for STM impact on committed units in contact
55-59	FAILCN	F5.3	On/off switch for STMGEN. FAILCN = 0 or blank means "no STM". STM traffic is generated if FAILCN .NE. 0.
62-66	PCONVR	F5.3	On/off switch for COMSYS. 3.0 = NO COMSYS play (any other value has no effect)

Card 3

Col.	Name	Format	
11-15	INTD	I5	INTD .GT. 0 means 'play Blue DF capability'. INTD = 0 means 'no Blue DF capability
16-20	INTR	I5	INTR .GT. 0 means 'play Red DF capability". INTR = 0 means 'no Red DF capability'.
21-25	ZL1M	F5.3	A DF device has a 'good fix' on a detected unit only if the DF intelligence level on that unit exceeds ZL1M
26-30	ZNTMN	F5.3	DF intelligence is not passed on to Div Arty unless at least ZNTMN (amount of intell) has been collected on at least 1 unit.
31-45	FAC(I) I=1,3	3F5.3	A multiplicative adjustment of DF intelligence on a unit. FAC(I) is based on the occurrence of I 'good fixes' on the unit. Typically FAC(1) = 0 < FAC(2) < FAC(3).

Card 4

Col.	Name	Format	
1-20	ICEW(I) I=1,4	415	Designate the mode/usage codes (see COMMEL User's Manual) for the message type which are to be intercepted by DF devices.
21-25	SFAC(1)	F5.1	If Blue DF is used, set SFAC(1) equal to the value of TWT(I,) (see cards 6-8) which When exceeded by a DF target, will assign highest artillery target priority.
26-30	SFAC(2)	F5.1	If Red DF is used, set SFAC(2) equal to the value of TWT(I,) (see cards 6-8) which, when exceeded by a DF target, will assign highest artillery target priority.

Card 5

Col.	Name	Format	
1-50	TFAC(I) I=1,10	10F5.3	Multiplicative DF intelligence factors which reduce DF intelligence with increasing time since last radio message transmission from a unit. TFAC(I) references a 10 minute interval during which a target unit last transmitted. The interval for I=1 is the most recent 10 minutes; the interval for I=9 is between 80 and 90 minutes ago.

Card 6

Col.	Name	Format	
1-50	TWT(1,I) I=1,10	10F5.3	A weighting factor (>0) which, when added to 1, becomes a multiplier of artillery target value for a unit of Type I on which DF intelligence has provided 1 good fix. Note: The model weights zero good fixes and one good fix equally.

Card 7

Col.	Name	Format	
1-50	TWT(2,I) I=1,10	10F5.3	Analogous to TWT (1,I) of card 6 except that TWT(2,I) applies to target units with 2 good fixes.

Card 8

Col.	Name	Format	
1-50	TWT(3,I) I=1,10	105.3	Analogous to TWT(1,I) of card 6 except that TWT(3,I) applies to target units with 3 good fixes

Card 9

Col.	Name	Format	
1		I1	"4"
9-20	SEED	O12	Random number seed (must to both odd and octal).
21-30	AVGJAM	F10.0	Mean of probability of an eligible arc being jammed.
31-40	STDJAM	F10.0	Standard deviation of probability of an eligible arc being jammed.
41-43	JAMDLY	I3	Delay time after a unit is placed until an eligible arc can be jammed
44-46		I3	Number of arc types to be jammed.
47-76		10I3	Types of arc that can be jammed.

Card 10

Col.	Name	Format	
1		I1	"5"
5-8	MPSTRT	I4	Time (in minutes) map plots begin.
19-22	MPINCR	I4	Time (in minutes) between map plots.

Card 11

Col.	Name	Format	
1		I1	"9"

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